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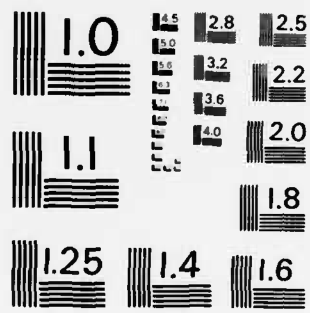
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NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO, CALIFORNIA 92152

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# TECHNIQUES FOR ESTIMATING PAY ENTRY BASE DATE ENLISTED PERSONNEL FORCE STRUCTURES FROM DATA CATEGORIZED BY TOTAL ACTIVE FEDERAL MILITARY SERVICE

Special Report 77-9 May 1977

# TECHNIQUES FOR ESTIMATING PAY ENTRY BASE DATE ENLISTED PERSONNEL FORCE STRUCTURES FROM DATA CATEGORIZED BY TOTAL ACTIVE FEDERAL MILITARY SERVICE

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## FOREWORD

The research and development effort described in this report was in support of the BUPERS Management Support Program (FAST Data Base) project. The overall objective of the FAST Data Base project is to provide the necessary R&D, analysis, and data processing support required to transform the computerized data bases used by the BUPERS Active Enlisted Plans Branch (PERS-212) from length-of-service (LOS) based on Pay Entry Base Date (PEBD) to LOS based on Total Active Federal Military Service (TAFMS). The effort described herein was one of the major tasks of the FAST Data Base Project.

Acknowledgements are due to Mr. Norman Lonsdale and Dr. Kenneth Leland for their valuable assistance during the data processing phases of this venture.

J. J. CLARKIN
Commanding Officer

## SUMMARY

### Problem

In response to DoD requirements for standard measures to evaluate personnel force structures, all branches of the armed services were instructed to calculate length of service (LOS) of enlisted personnel on the basis of Total Active Federal Military Service (TAFMS). The cost of a personnel force structure defined in terms of TAFMS is not directly obtainable, at least for pay purposes, because basic pay is related to the LOS of personnel computed by Pay Entry Base Date (PEBD). To compute the cost of future enlisted inventories, it was necessary to develop a technique to estimate the cost of a TAFMS force structure matrix.

### Objective

The purpose of this research effort is to develop and assess the accuracy of mathematical techniques which estimate PEBD force structure data (and, concurrently, obtain cost estimates) from TAFMS force structure data.

### Approach

Statistical techniques involving marginal estimation, cell-by-cell conversion, and lagged correlation and regression models were developed and evaluated in terms of their ability to both accurately estimate individual force structure cells and obtain the cost of the entire force structure matrix. The data base studied consisted of series of annual TAFMS and PEBD force structure matrices for the period FY 1966-FY 1976. Analysis consisted of applying various statistical techniques to 6-year streams of data and applying the obtained results to convert TAFMS data of the following year to PEBD. In this way, estimates of PEBD force structures for FY 1973-FY 1976 were obtained and compared to the actual PEBD matrix of the corresponding year. Choice of statistical technique for implementation was based upon both theoretical considerations and the result of these comparisons.

### Results

1. For FY 1973-FY 1976, a 6-year "best" regression technique produced PEBD force structure matrices whose standardized costs never differed by more than $346,000 from the standardized costs obtained from the actual PEBD force structure matrix of the corresponding year.

2. Best estimation techniques produced total cost estimates that were within .14 percent of actual standardized costs.

3. The mean absolute cell deviation between estimated and observed PEBD force structure matrices for FY 1973-FY 1976 was within the range from 50 to 140 individuals when either an apportioned prior-year conversion factor or highest-correlation regression procedure was utilized.

4. Statistical techniques based solely upon estimation of force structure paygrade or LOS totals (marginal methods) produced estimates consistently inferior to those obtained by either apportioned prior-year conversion factor or lagged correlation/regression methods.

5. Naive costing of TAFMS data underestimated actual standardized cost by approximately 1 percent, or roughly \$2-\$3 million.

## Conclusions

1. A statistical technique based upon apportioned highest lagged correlation linear regression estimates provided highly accurate force-structure cost estimates.

2. A statistical technique based upon apportionment of prior-year conversion factors also provided surprisingly accurate cost estimates.

3. Utilization of either an apportioned linear regression or apportioned prior-year conversion factor technique substantially improved estimates obtained from naive costing of TAFMS data matrices.

## Recommendation

A statistical technique based upon apportioned linear regression of prior-year cell conversion factors should be chosen as the method to estimate the cost of TAFMS data matrices.

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# INTRODUCTION

## Problem

Length of service (LOS) of enlisted Navy personnel may be defined via a number of alternative criteria. These definitions include: (1) Active Duty Service Date (ADSD), (2) Total Time of Active Federal Military Service (TAFMS), and (3) Pay Entry Base Date (PEBD). ADSD LOS is defined as only that time accrued while serving on Navy active duty; TAFMS LOS, as all time accrued on active duty with any military branch; and PEBD LOS, as all time accrued by an individual that affects his pay status, including time served in the inactive Navy reserve as well as on active duty.

Although data presented in terms of TAFMS conforms to DoD requirements for standard measures to evaluate personnel force structures, it may not be used to directly obtain Navy personnel costs. Naive computation of payroll data on the basis of TAFMS force structures will ordinarily result in significant cost underestimates since LOS computed by PEBD is frequently greater. Thus, to estimate the cost of projected enlisted personnel force structures, it is necessary to develop procedures to convert data which has been categorized on the basis of TAFMS to PEBD.

## Purpose

The purpose of this effort was to develop and assess the accuracy of procedures to estimate PEBD force structure data from corresponding information categorized by TAFMS.

## Background

DoD Instruction 1300.14, Subj: Enlisted Personnel Management Planning and Reporting, dated 19 November 1974 directed all services to compute LOS of enlisted personnel on the basis of TAFMS. Since the cost of force structures computed in this manner is not directly calculable, it was necessary to develop procedures that estimate PEBD force structures from TAFMS data.

## APPROACH

### Data Source

The primary data base for this study consisted of 11-year sequences of ALNAV TAFMS and ALNAV PEBD inventories extending over the period from FY 1966 through FY 1976.[1]

### Criteria for Assessing Accuracy of Conversion Techniques

The two criteria employed for judging the accuracy of conversion techniques are discussed below.

#### Mean Absolute Deviation Between Corresponding Estimated and Actual PEBD Cells

Let $P_{ijk}$ represent the actual PEBD inventory of individuals with length of service (LOS) j ($[0\text{-}1] \le j \le [30+]$) and enlisted paygrade k ($[E\text{-}1] \le k \le [E\text{-}9]$) for fiscal year i ($66 \le i \le 76$).[2] Let $\hat{P}_{ijk}$ represent the estimated PEBD inventory for fiscal year i of individuals with length of service j ($1 \le j \le 31$) and paygrade k ($1 \le k \le 9$), based upon a specific TAFMS to PEBD force-structure conversion technique. For a specific fiscal year, the mean absolute deviation (MAD) between corresponding estimated and actual PEBD cell inventories is defined as

$$MAD = \sum_{j=1}^{31} \sum_{k=1}^{9} |\hat{P}_{ijk} - P_{ijk}|/279.$$

This measure was chosen since it shows, on the average, the difference between the corresponding converted (estimated) and true (actual) cell values of the PEBD force structure under study. The denominator of this expression, 31x9=279, is derived fron the fact that there are 279 cells in a PEBD force structure matrix. Clearly, the closer this measure is to zero, the more accurate the fit between converted and true values. The value of MAD cannot equal zero unless the estimated and actual force structure matrices are identical. (See Dixon & Massey (1969) for a general discussion of mean absolute deviation.)

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[1]This data is available upon request from the Navy Personnel Research and Development Center, Code 303.

[2]For notational simplicity, j=[0,1]=1, j=[1,2]=2, ..., j=[30+]=31; k=[E-1]=1, k=[E-2]=2, ..., k=[E-9]=9.

Standardized Cost

The cost of a particular PEBD force structure matrix may be obtained in the following way. Let $C_{ijk}$ represent the monthly pay of individuals in length of service cell j, paygrade k, for fiscal year i. The total actual monthly pay of all individuals for fiscal year i may then be computed as

$$COST_i = \sum_{j=1}^{31} \sum_{k=1}^{9} C_{ijk} P_{ijk}.$$

Additionally, total monthly pay based upon conversion of TAFMS to PEBD data may be estimated to be

$$\hat{COST}_i = \sum_{j=1}^{31} \sum_{k=1}^{9} C_{ijk} \hat{P}_{ijk}.$$

A measure of the ability of a conversion technique to "cost" a given force structure may then be calculated as the difference between the estimated and actual total monthly pay, $\hat{COST}_i - COST_i$. A positive value of this expression indicates an overestimate of cost while a negative value indicates a cost underestimate. The percentage difference in costs, $(\hat{COST}_i - COST_i)/COST_i$, may also be used as a measure of cost accuracy.

A specific pay table was used throughout this study to standardize comparisons among conversion techniques over time. To approximate current pay conditions, the enlisted personnel pay schedule in effect as of 30 June 1975 was selected. This schedule is presented in Table 1.

Table 1

Pay Schedule for Enlisted Personnel
as of 30 June 1975

| Years of Service (PEBD) | Paygrade | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | E-1 | E-2 | E-3 | E-4 | E-5 | E-6 | E-7 | E-8 | E-9 |
| 0-1 | $344.10 | $383.40 | $398.40 | $414.30 | $430.80 | $490.80 | $ 568.20 | $ 813.90 | $ 969.90 |
| 1-2 | 344.10 | 383.40 | 398.40 | 414.30 | 430.80 | 490.80 | 568.20 | 813.90 | 969.90 |
| 2-3 | 344.10 | 383.40 | 420.30 | 437.40 | 469.20 | 535.20 | 613.20 | 813.90 | 969.90 |
| 3-4 | 344.10 | 383.40 | 437.10 | 462.90 | 491.70 | 557.40 | 636.00 | 813.90 | 969.90 |
| 4-5 | 344.10 | 383.40 | 454.20 | 499.20 | 513.00 | 580.50 | 658.20 | 813.90 | 969.90 |
| 5-6 | 344.10 | 383.40 | 454.20 | 499.20 | 513.00 | 580.50 | 658.20 | 813.90 | 969.90 |
| 6-7 | 344.10 | 383.40 | 454.20 | 518.70 | 546.60 | 602.70 | 681.00 | 813.90 | 969.90 |
| 7-8 | 344.10 | 383.40 | 454.20 | 518.70 | 546.60 | 602.70 | 681.00 | 813.90 | 969.90 |
| 8-9 | 344.10 | 383.40 | 454.20 | 518.70 | 568.80 | 624.90 | 702.30 | 813.90 | 969.90 |
| 9-10 | 344.10 | 383.40 | 454.20 | 518.70 | 568.80 | 624.90 | 702.30 | 813.90 | 969.90 |
| 10-11 | 344.10 | 383.40 | 454.20 | 581.70 | 591.60 | 647.40 | 724.50 | 836.70 | 969.90 |
| 11-12 | 344.10 | 383.40 | 454.20 | 581.70 | 591.60 | 647.40 | 724.50 | 836.70 | 969.90 |
| 12-13 | 344.10 | 383.40 | 454.20 | 581.70 | 613.20 | 681.00 | 747.30 | 858.90 | 992.10 |
| 13-14 | 344.10 | 383.40 | 454.20 | 581.70 | 613.20 | 681.00 | 747.30 | 858.90 | 992.10 |
| 14-15 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 702.30 | 781.20 | 881.40 | 1014.60 |
| 15-16 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 702.30 | 781.20 | 881.40 | 1014.60 |
| 16-17 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 724.50 | 803.10 | 904.20 | 1038.00 |
| 17-18 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 724.50 | 803.10 | 904.20 | 1038.00 |
| 18-19 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 825.60 | 925.50 | 1060.80 |
| 19-20 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 825.60 | 925.50 | 1060.80 |
| 20-21 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 836.70 | 948.30 | 1081.80 |
| 21-22 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 836.70 | 948.30 | 1081.80 |
| 22-23 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 892.80 | 1003.80 | 1138.80 |
| 23-24 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 892.80 | 1003.80 | 1138.80 |
| 24-25 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 892.80 | 1003.80 | 1138.80 |
| 25-26 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 892.80 | 1003.80 | 1138.80 |
| 26-27 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 1003.80 | 1116.00 | 1249.20 |
| 27-28 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 1003.80 | 1116.00 | 1249.20 |
| 28-29 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 1003.80 | 1116.00 | 1249.20 |
| 29-30 | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 1003.80 | 1116.00 | 1249.20 |
| 30+ | 344.10 | 383.40 | 454.20 | 581.70 | 624.90 | 735.90 | 1003.80 | 1116.00 | 1249.20 |

## Conversion Methodology

Let f represent a function that operates on a TAFMS force structure matrix and converts its cell values into those of a PEBD force structure matrix. Notationally, this may be written as:

$$||\hat{P}_{ijk}|| = f||T_{ijk}||$$

where $||\hat{P}_{ijk}||$ and $||T_{ijk}||$ represent the estimated PEBD and actual TAFMS force structure matrices for fiscal year i. A number of conversion functions, f, was investigated, which may be categorized as (1) Marginal Techniques, (2) Cell-by-Cell Conversion, and (3) Regression Estimates. Each of these general approaches is discussed below.

### Marginal Techniques

This category of conversion techniques employed methods involving estimation of cell values based upon initial establishment of marginal, or total, vector values. The specific marginal techniques investigated include the following:

Estimation of PEBD Column Percentage Distributions. Since PEBD column marginals (paygrade totals) must be equal to TAFMS column marginals of the corresponding year, the known TAFMS marginal totals may be allocated to individual PEBD LOS cells in accordance with historical PEBD column percentage distributions. Notationally, let $T_{i \cdot k} = P_{i \cdot k}$ represent the total number of individuals in paygrade k on the first day of fiscal year i. For specific values of i and k ($1 \leq k \leq 9$), a PEBD column percentage distribution is a set of values $\{p^{(c)}_{i1k}, p^{(c)}_{i2k}, \ldots, p^{(c)}_{i31k}\}$ such that $p^{(c)}_{ijk} \geq 0$ for all j ($1 \leq j \leq 31$), k ($1 \leq k \leq 9$), and $\sum_{j=1}^{31} p^{(c)}_{ijk} = 1$ for all k ($1 \leq k \leq 9$). For any specific year, i, if all $p^{(c)}_{ijk} = \frac{P_{ijk}}{P_{i \cdot k}}$ are known, the actual PEBD inventory cell values may be obtained using the formula

$$P_{ijk} = p^{(c)}_{ijk} T_{i \cdot k} = p^{(c)}_{ijk} P_{i \cdot k}.$$

In practice, the values of $p_{ijk}^{(c)}$ are unknown since the required PEBD matrix is not available. Therefore, it is necessary to use historical data to obtain estimates, $\hat{p}_{ijk}^{(c)}$ of all $p_{ijk}^{(c)}$.

Two specific techniques were used to estimate $p_{ijk}^{(c)}$ for fiscal years 1973, 1974, 1975, and 1976. The first technique is simple application of the previous year's PEBD column percentage distribution as an estimate of the current year's distribution. In this case,

$$\hat{P}_{ijk} = p_{i-1jk}^{(c)} T_{i \cdot k}.$$

This method is based upon the assumption that PEBD column percentage distributions are not likely to change appreciably from one year to the next. The second technique consists of obtaining 6-year moving ratio estimates of the PEBD column percentage distribution. In this case,

$$\hat{p}_{ijk}^{(c)} = \sum_{i^*=i-6}^{i^*=i-1} P_{i^*jk} / \sum_{i^*=i-6}^{i^*=i-1} P_{i^* \cdot k}$$

for i = 1973, 1974, 1975, 1976. This is equivalent to obtaining the column percentage distribution of the sum of the six PEBD force structure matrices prior to the year to be estimated and using this distribution as an estimate of the current year PEBD column percentage distribution. This technique is essentially one of averaging data over a period of time to obtain an estimate of the value in question. (For a complete discussion of ratio estimation, see Cochran, 1963).

Estimation of PEBD Row (LOS) Percentage Distributions. If the row marginal totals of the PEBD matrix to be estimated were known, then individual cell inventories could be estimated by applying historical PEBD row percentage distributions to these values. Notationally, let $P_{ij.}$ represent the total number of individuals within LOS cell j on the first day of fiscal year i. For specific values of i and j ($1 \leq j \leq 31$), a PEBD row percentage distribution is a set of values $\{p_{ij1}^{(r)}, p_{ij2}^{(r)}, \ldots, p_{ij9}^{(r)}\}$ such that $p_{ijk}^{(r)} \geq 0$ for all j ($1 \leq j \leq 31$), k ($1 \leq j \leq 9$), and $\sum_{k=1}^{9} p_{ijk}^{(r)} = 1$ for all j ($1 \leq j \leq 31$). For any specific year, i, if all $p_{ijk}^{(r)} = \frac{P_{ijk}}{P_{ij.}}$ are known, the actual PEBD inventory cell values may be obtained using the formula

$$P_{ijk} = p_{ijk}^{(r)} P_{ij.} \ .$$

Since the required PEBD matrix is not available, the values of $p^{(r)}_{ijk}$ and $P_{ij.}$ are unknown. It is therefore necessary to use historical data to obtain estimates $\hat{P}_{ij.}$, of $P_{ij.}$, and of the current year row percentage distribution. $\hat{P}_{ijk} = \hat{p}^{(r)}_{ijk} \times \hat{P}_{ij.}$ may then serve as an estimate of $P_{ijk}$. This study used 6-year moving ratio estimates.

$$\left( \hat{p}^{(r)}_{ijk} = \sum_{i^*=i-6}^{i-1} P_{i^*jk} / \sum_{i^*=i-6}^{i-1} P_{i^*j.} \right) ,$$

of the PEBD row percentage distribution.

To obtain estimates of $P_{ij.}$, it was noted that one-year lagged correlation coefficients between the variables $P_{ij.}/T_{ij.}$ and $P_{ij-1.}/T_{ij-1.}$ [i.e., the correlation coefficient between pairs of TAFMS to PEBD conversion factors $(P_{ij.}/T_{ij.}, P_{i-1j-1.}/T_{i-1j-1.})$] for $2 \leq j \leq 31$ and $i = 1967$, 1968, ..., 1975 indicate a strong lagged relationship for LOS > 6-7. These coefficients are presented in Table 2. This implies that the marginal LOS conversion factor, $P_{ij.}/T_{ij.}$ moves downward or "ages" through the force structure matrix over time. Using this lagged relationship, estimates of $P_{ij.}$ were obtained from the equation,

$$\left( \hat{P}_{ij.} = P_{i-1j-1.}/T_{i-1j-1.} \right) \times T_{ij.},$$

for LOS > 6-7. Because the lagged correlation coefficients were small for LOS $\leq$ 6-7, 6-year moving ratio estimates,

$$\left( \sum_{i^*=i-6}^{i-1} P_{i^*j.} / \sum_{i^*=i-6}^{i-1} T_{i^*j.} \right)$$

were used in place of $P_{i-1j-1.}/T_{i-1j-1.}$ as estimates of the current year conversion factor. In summary, the formula

$$\hat{P}_{ijk} = \left( \sum_{i^*=i-6}^{i-1} P_{i^*jk} / \sum_{i^*=i-6}^{i-1} P_{i^*j.} \right) \left( P_{i-1,j-1.}/T_{i-1,j-1.} \right) T_{ij.} \quad \text{for LOS > 6-7}$$

$$\hat{P}_{ijk} = \left( \sum_{i^*=i-6}^{i-1} P_{i^*jk} / \sum_{i^*=i-6}^{i-1} P_{i^*j.} \right) \left( \sum_{i^*=i-6}^{i-1} P_{i^*j.} / \sum_{i^*=i-6}^{i-1} T_{i^*j.} \right) T_{ij.}$$

$$= \left( \sum_{i^*=i-6}^{i-1} P_{i^*jk} / \sum_{i^*=i-6}^{i-1} T_{i^*j.} \right) T_{ij.} \qquad \text{for LOS} \leq 6\text{-}7$$

served as a row marginal procedure to estimate the PEBD force structure matrix.

Table 2

One-Year Lagged Correlation Coefficients Between Pairs of Conversion Factors for Row Marginals ($P_{ij.}/T_{ij.}$, $P_{i-1,j-1.}/T_{i-1,j-1.}$)

| Years of Service | Lagged Correlation Coefficient |
|---|---|
| 1-2 | .7114 |
| 2-3 | .6830 |
| 3-4 | .5911 |
| 4-5 | .1201 |
| 5-6 | .1690 |
| 6-7 | .1208 |
| 7-8 | .9869 |
| 8-9 | .9819 |
| 9-10 | .9974 |
| 10-11 | .9947 |
| 11-12 | .9971 |
| 12-13 | .9990 |
| 13-14 | .9996 |
| 14-15 | .9988 |
| 15-16 | .9912 |
| 16-17 | .9916 |
| 17-18 | .9947 |
| 18-19 | .9983 |
| 19-20 | .9816 |
| 20-21 | .9649 |
| 21-22 | .9860 |
| 22-23 | .9783 |
| 23-24 | .9720 |
| 24-25 | .9919 |
| 25-26 | .9939 |
| 26-27 | .9968 |
| 27-28 | .9895 |
| 28-29 | .9968 |
| 29-30 | .9942 |
| 30+ | .9023 |

For the above procedure, and all other procedures to be discussed in this report, it is possible that

$$\sum_{j=1}^{31} \hat{P}_{ijk} = \hat{P}_{i \cdot k} \neq T_{i \cdot k}$$

for some k, $1 \leq k \leq 9$. Since $P_{i \cdot k}$ must equal $T_{i \cdot k}$, the following scheme is used to apportion the difference between the known and estimated PEBD paygrade marginal totals. The difference, $T_{i \cdot k} - \hat{P}_{i \cdot k}$, is distributed to individual LOS cells within paygrade k on a constant percentage basis. That is, $[(T_{i \cdot k} - \hat{P}_{i \cdot k})/\hat{P}_{i \cdot k}] \times \hat{P}_{ijk}$ is added to each cell inventory. When this expression is negative, the effect is to decrease the values of each non-zero cell by a constant proportion. It can easily be seen that

$$\sum_{j=1}^{31} \hat{P}^{(A)}_{ijk} = T_{i \cdot k}$$

where $\hat{P}^{(A)}_{ijk}$ represents the apportioned value of $\hat{P}_{ijk}$.

## Cell-by-Cell Conversion

This group of conversion techniques estimates current year TAFMS/PEBD cell conversion factors individually. A TAFMS/PEBD conversion factor matrix, $\nu$, may be defined as a matrix of numbers such that

$$\hat{P}_{ijk} = \nu_{ijk} \times T_{ijk}$$

for $1 \leq j \leq 31$; $1 \leq k \leq 9$. Since

$$P_{ijk} = (P_{ijk}/T_{ijk}) \times T_{ijk},$$

estimation of $||\nu_{ijk}||$ is equivalent to the problem of estimating $||P_{ijk}/T_{ijk}||$. The five cell-by-cell conversion methods investigated are discussed below.

Six-Year Moving Ratio Estimate. This method estimates $||P_{ijk}/T_{ijk}||$ by the matrix

$$|| \sum_{i^*=i-6}^{i^*=i-1} P_{i^*jk} / \sum_{i^*=i-6}^{i^*=i-1} T_{i^*jk} ||.$$

Ratio estimation procedures are employed because the conversion matrix to be estimated is constructed of factors with variable numerators and denominators. (For a full discussion of the mathematical properties of ratio estimates, see Cochran, 1963).

Previous Year TAFMS/PEBD Conversion Factor. This method employs $||P_{i-1,jk}/T_{i-1,jk}||$ as an estimate of $||P_{ijk}/T_{ijk}||$. This technique is based upon the assumption that the relationship between TAFMS and PEBD force structure matrices is not likely to change appreciably from one year to the next.

Previous Year TAFMS/PEBD Conversion Factor of Prior LOS Cell. This technique estimates $||P_{ijk}/T_{ijk}||$ with the matrix $||P_{i-1,j-1,k}/T_{i-1,j-1,k}||$ for $j>1$ and $||P_{i-1,jk}/T_{i-1,jk}||$ for $j=1$.

Previous Year TAFMS/PEBD Conversion Factor of Prior LOS Cell and Next Lower Paygrade. This technique estimates $||P_{ijk}/T_{ijk}||$ using $||P_{i-1,j-1,k-1}/T_{i-1,j-1,k-1}||$ for $j>1$, $k>1$; $||P_{i-1,j-1,k}/T_{i-1,j-1,k}||$ for $j>1$, $k=1$; and $||P_{i-1,jk}/T_{i-1,jk}||$ for $j=1$.

Selection of TAFMS/PEBD Conversion Factor Based Upon Cell With Highest Lagged Correlation Coefficient with Cell to be Estimated. This method estimates individual $P_{ijk}/T_{ijk}$ conversion factors by using

1. $P_{i-1,jk}/T_{i-1,jk}$, or

2. $P_{i-1,j-1,k}/T_{i-1,j-1,k}$, or

3. $P_{i-1,j-1,k-1}/T_{i-1,j-1,k-1}$.

The specific factor to be used is based upon determination of the conversion factor with the highest single-year lagged correlation coefficient with $P_{ijk}/T_{ijk}$. In order to maintain consistency with other estimation techniques for all years under study, correlation coefficients were based upon the 6-year sequence i-6, i-5, ..., i-1 when estimating the conversion factor for year i. As an example, suppose an estimate of the conversion factor for cell j=2, k=3 was desired for FY 1974. Three correlation coefficients between pairs of matrix cells would be computed for the following sequences of data:

$$(P_{68,2,3}/T_{68,2,3},\ P_{67,2,3}/T_{67,2,3});\ (P_{69,2,3}/T_{69,2,3},\ P_{68,2,3}/T_{68,2,3});\ \ldots;\ (P_{73,2,3}/T_{73,2,3},\ P_{72,2,3}/T_{72,2,3}) \quad (1)$$

$$(P_{68,2,3}/T_{68,2,3},\ P_{67,1,3}/T_{67,1,3});\ (P_{69,2,3}/T_{69,2,3},\ P_{68,1,3}/T_{68,1,3});$$

$$\ldots;\ (P_{73,2,3}/T_{73,2,3},\ P_{72,1,3}/T_{72,1,3}) \qquad (2)$$

$$(P_{68,2,3}/T_{68,2,3},\ P_{67,1,2}/T_{67,1,2});\ (P_{69,2,3}/T_{69,2,3},\ P_{68,1,2}/T_{68,1,2});$$

$$\ldots;\ (P_{73,2,3}/T_{73,2,3},\ P_{72,1,2}/T_{72,1,2}) \qquad (3)$$

Tables 3, 4, and 5 present the matrix of correlation coefficients for FY 1974 computed as in (1), (2), and (3) respectively.[3] For illustrative purposes, cell (2,3) has been circled in all tables. Since the highest lagged correlation coefficient for cell (2,3) is located in Table 5, the conversion factor $P_{74,2,3}/T_{74,2,3}$ will be estimated as $P_{73,1,2}/T_{73,1,2}$. Table 6 indicates which correlation coefficient (1), (2), or (3) was highest for each cell for fiscal year 1974. Note that coefficient (2) cannot be computed for j=1 and coefficient (3) cannot be computed for j=1 or k=1.

The last three conversion techniques discussed (Previous Year TAFMS/PEBD Conversion Factor of Prior LOS Cell, Previous Year TAFMS/PEBD Conversion Factor of Prior LOS Cell and Next Lower Paygrade, and Selection of TAFMS/PEBD Conversion Factor Based Upon Cell With Highest Lagged Correlation Coefficient With Cell to be Estimated) are based upon the usual year-to-year movement of individuals through the force structure. This movement consists of aging (i.e., a 1-year increase in LOS) with either no change or a 1-unit increase in paygrade).

All values obtained by cell-by-cell conversion are then percentage apportioned so as to equate TAFMS and PEBD column paygrade marginal totals.[4]

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[3]Lagged correlation coefficients and highest correlation matrices for FY 1973, 1975, and 1976 are available upon request from NAVPERSRANDCEN, Code 303.

[4]Whenever an infinite cell conversion factor was encountered; that is, whenever the numerator of the factor was positive and the denominator was zero, a 6-year moving ratio column percentage estimate of the cell was used. Whenever a conversion factor of 0/0 was encountered, zero was used as the cell conversion factor.

Table 3

One-Year Lagged Correlation Coefficients Between Pairs of Conversion Factors $(P_{ijk}/T_{ijk}, P_{i-1,jk}/T_{i-1,jk})$--Fiscal Year 1974

| Years of Service | Paygrade | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | E-1 | E-2 | E-3 | E-4 | E-5 | E-6 | E-7 | E-8 | E-9 |
| 0-1 | -.0774 | -.4440 | -.3397 | -.1117 | .6538 | .0118 | -.2462 | .0000 | .0000 |
| 1-2 | -.1185 | .0397 | -.3577 | -.5426 | -.4271 | .5319 | -.1250 | .0000 | .0000 |
| 2-3 | .1991 | .2841 | -.0810 | -.2411 | .0562 | .9897 | -.6353 | .0000 | .0000 |
| 3-4 | .5401 | .5395 | .4840 | .3073 | .0272 | .4916 | -.0593 | -.2928 | .0000 |
| 4-5 | .3833 | .1850 | -.1014 | .4884 | .6123 | -.2173 | -.0702 | -.2000 | .0000 |
| 5-6 | .8157 | .3252 | .2364 | .1807 | .2008 | -.0961 | -.0087 | .0000 | .0000 |
| 6-7 | -.6277 | .7729 | .0669 | .3585 | .7600 | .4517 | -.2162 | .0000 | .0000 |
| 7-8 | -.0257 | .2760 | .3826 | .1881 | .4827 | .5731 | .8808 | .0000 | .0000 |
| 8-9 | -.4004 | -.3112 | -.0106 | .2502 | .5101 | .7066 | .1576 | .0000 | .0000 |
| 9-10 | -.1601 | -.2080 | -.0473 | .2139 | .4367 | .3467 | .5841 | -.2000 | .0000 |
| 10-11 | -.1351 | -.7475 | -.6948 | .5219 | .1493 | .0914 | .2185 | -.3494 | .0000 |
| 11-12 | -.6650 | -.3617 | .0877 | .0178 | .6181 | .6725 | .5617 | .3635 | .0000 |
| 12-13 | -.5997 | .5779 | .0828 | .6369 | .9053 | .8671 | .7943 | .0833 | .0000 |
| 13-14 | .0746 | .1553 | .1607 | .8429 | .7506 | .8235 | .7508 | .2904 | .3009 |
| 14-15 | -.2000 | .1948 | -.3730 | .8314 | .8062 | .7654 | .7698 | .7225 | .5442 |
| 15-16 | .0000 | -.2000 | -.2358 | .4803 | .6674 | .3908 | .1975 | -.1056 | -.1334 |
| 16-17 | -.2000 | .0000 | -.1071 | -.3640 | .2575 | .2339 | .2332 | .1082 | -.2990 |
| 17-18 | -.2000 | -.3162 | -.0181 | .4206 | -.1829 | .4467 | .5750 | .3364 | .4925 |
| 18-19 | -.6799 | -.2000 | -.2046 | .4394 | .6625 | .8357 | .5871 | .5075 | .3524 |
| 19-20 | .2500 | -.2000 | -.0956 | .8284 | .8310 | .8209 | .6127 | .4887 | .5702 |
| 20-21 | .0000 | .0000 | .5483 | .2714 | .7251 | .4578 | .3387 | -.0815 | .6505 |
| 21-22 | .0000 | .0000 | -.1976 | .6643 | .5506 | .3696 | .1823 | -.1862 | .4892 |
| 22-23 | .0000 | -.2000 | .4123 | .1581 | .5004 | .2335 | .2614 | .3622 | .8185 |
| 23-24 | .0000 | .0000 | -.4781 | .3078 | -.4250 | .0535 | .3896 | .5270 | .7090 |
| 24-25 | .0000 | .0000 | .0000 | -.1200 | -.3996 | .0850 | .2990 | .4594 | .4389 |
| 25-26 | .0000 | .0000 | .2928 | -.1746 | .0530 | .2304 | .3390 | .3846 | .3788 |
| 26-27 | .0000 | .0000 | -.2000 | -.4103 | .1571 | .0497 | .3627 | .3669 | .2626 |
| 27-28 | .0000 | .0000 | -.2000 | -.1260 | .1888 | .5289 | .1185 | .4033 | .2148 |
| 28-29 | .0000 | .0000 | -.2000 | -.5570 | -.4431 | .0131 | .0221 | .1590 | .1126 |
| 29-30 | .0000 | .0000 | -.2000 | .8216 | .5018 | .5344 | .1380 | .3333 | -.0518 |
| 30+ | .0000 | .0000 | .0000 | -.0771 | -.3649 | .8240 | .3905 | .2940 | .2613 |

Table 4

One-Year Lagged Correlation Coefficients Between Pairs of Conversion Factors ($P_{ijk}/T_{ijk}$, $P_{i-1,j-1,k}/T_{i-1,j-1,k}$)--Fiscal Year 1974

| Years of Service | Paygrade | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | E-1 | E-2 | E-3 | E-4 | E-5 | E-6 | E-7 | E-8 | E-9 |
| 1-2 | .1208 | .2839 | .2760 | .4748 | .7444 | .8487 | .4510 | .0000 | .0000 |
| 2-3 | -.2367 | -.3047 | .1836 | .4132 | .2924 | .9666 | .3976 | .0000 | .0000 |
| 3-4 | .4806 | .4437 | -.1748 | -.0820 | .8758 | .7673 | -.2562 | .0000 | .0000 |
| 4-5 | -.3889 | -.0826 | .4876 | -.0593 | .8759 | -.1187 | .4850 | 1.0000 | .0000 |
| 5-6 | -.1371 | .1175 | .8514 | -.1134 | .6767 | .9092 | .5248 | .0000 | .0000 |
| 6-7 | -.2744 | .7297 | .4906 | .8709 | .9845 | .9418 | -.1712 | .0000 | .0000 |
| 7-8 | -.1805 | .3634 | .8595 | .7901 | .9076 | .9394 | -.3658 | .0000 | .0000 |
| 8-9 | -.0250 | .0922 | .4566 | .9608 | .8919 | .9623 | .7353 | .0000 | .0000 |
| 9-10 | .6097 | .4990 | .7353 | .6680 | .9785 | .9875 | .6894 | .0000 | .0000 |
| 10-11 | -.0320 | -.7792 | .0549 | .9036 | .9797 | .9978 | .9465 | .9655 | .0000 |
| 11-12 | .5152 | -.3956 | -.2083 | .3155 | .9439 | .9780 | .8872 | -.2450 | .0000 |
| 12-13 | -.2552 | -.1036 | .6689 | .8707 | .9855 | .9983 | .9885 | .0181 | .0000 |
| 13-14 | .5966 | .7637 | .8519 | .9699 | .9926 | .9965 | .9976 | .5420 | .0000 |
| 14-15 | -.3568 | .2955 | .5940 | .9757 | .9972 | .9946 | .9958 | .9157 | .5334 |
| 15-16 | .2000 | -.3525 | .1315 | .9300 | .9949 | .9953 | .9876 | .9950 | .6338 |
| 16-17 | -.2928 | -.2000 | -.0972 | .6891 | .9970 | .9795 | .9809 | .9639 | .8056 |
| 17-18 | -.2000 | .0000 | .2871 | .8577 | .9482 | .9887 | .9933 | .9817 | .9144 |
| 18-19 | -.3162 | -.3162 | .6939 | .9092 | .9883 | .9990 | .9817 | .9818 | .9854 |
| 19-20 | -.0971 | -.2000 | .9340 | .9295 | .9434 | .9920 | .9914 | .9867 | .9232 |
| 20-21 | .0000 | .0000 | .4547 | .0689 | .9914 | .9703 | .9504 | .9328 | .9439 |
| 21-22 | .0000 | .0000 | .7517 | .8426 | .9459 | .9969 | .9911 | .9805 | .5880 |
| 22-23 | .0000 | .0000 | -.8779 | .8935 | .9809 | .9831 | .9823 | .9948 | .9869 |
| 23-24 | .0000 | .0000 | .4665 | .3637 | .7705 | .9584 | .9883 | .9909 | .9831 |
| 24-25 | .0000 | .0000 | .2389 | .8158 | .3307 | .9153 | .9965 | .9982 | .9928 |
| 25-26 | .0000 | .0000 | .7746 | .3618 | .4532 | .9809 | .9962 | .9979 | .9935 |
| 26-27 | .0000 | .0000 | .2928 | .6280 | .8643 | .9488 | .9839 | .9976 | .9981 |
| 27-28 | .0000 | .0000 | 1.0000 | .8322 | .9250 | .9827 | .9879 | .9973 | .9891 |
| 28-29 | .0000 | .0000 | 1.0000 | -.5091 | .9518 | .7860 | .9805 | .9933 | .9946 |
| 29-30 | .0000 | .0000 | 1.0000 | .7273 | .8570 | .6837 | .9543 | .9845 | .9813 |
| 30+ | .0000 | .0000 | .0000 | .2274 | .5943 | .9074 | .6341 | .5912 | .9435 |

Table 5

One-Year Lagged Correlation Coefficients Between Pairs of Conversion Factors ($P_{ijk}/T_{ijk}$, $P_{i-1,j-1,k-1}/T_{i-1,j-1,k-1}$)--Fiscal Year 1974

| Years of Service | Paygrade | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | E-2 | E-3 | E-4 | E-5 | E-6 | E-7 | E-8 | E-9 |
| 1-2 | -.4016 | .7281 | .7684 | .4013 | -.3303 | -.2343 | .0000 | .0000 |
| 2-3 | -.1235 | -.1894 | .6738 | .3907 | .0677 | .4660 | .0000 | .0000 |
| 3-4 | .5118 | .3804 | -.1145 | .7191 | -.0787 | .4718 | -.5709 | .0000 |
| 4-5 | -.0908 | .6802 | -.6251 | .2814 | .2298 | .2426 | -.7408 | .0000 |
| 5-6 | -.3315 | .4367 | .8903 | .7411 | .0419 | -.4558 | .0000 | .0000 |
| 6-7 | .4025 | .2770 | .8742 | .1130 | .8487 | .0221 | .0000 | .0000 |
| 7-8 | .1607 | .6817 | .7541 | .5212 | .9009 | -.8046 | .0000 | .0000 |
| 8-9 | .2380 | .1094 | .2037 | .4825 | .9335 | -.4522 | -.3735 | .0000 |
| 9-10 | -.5394 | .3374 | -.2362 | .6861 | .9955 | .7749 | -.7421 | .0000 |
| 10-11 | .6039 | -.5044 | .7852 | -.5617 | .9783 | .9049 | -.1370 | .0000 |
| 11-12 | .7190 | -.1314 | .2709 | .1518 | .8834 | .9614 | .7892 | .0000 |
| 12-13 | .6225 | -.3336 | .4055 | .5969 | .9889 | .9983 | .7779 | .0000 |
| 13-14 | -.1605 | .4670 | .7213 | .9198 | .9765 | .9829 | .9223 | .7152 |
| 14-15 | -.3704 | .2455 | .7037 | .9115 | .9743 | .9934 | .9847 | .6881 |
| 15-16 | -.2000 | .3256 | -.4223 | .8401 | .9762 | .9803 | .8798 | .9191 |
| 16-17 | .8783 | .0613 | .3112 | .7224 | .8053 | .9237 | .9856 | .9811 |
| 17-18 | -.2000 | .0000 | .7289 | -.0689 | .7837 | .9428 | .9760 | .9693 |
| 18-19 | 1.0000 | -.4502 | .5274 | .6140 | .9171 | .9694 | .9535 | .9636 |
| 19-20 | -.4300 | -.5043 | .1857 | .8002 | .9698 | .9881 | .9428 | .9760 |
| 20-21 | .0000 | .3457 | -.8529 | .7332 | .9865 | .9507 | .9507 | .9356 |
| 21-22 | .0000 | -.2158 | -.7978 | .8908 | .9186 | .9859 | .8828 | .5936 |
| 22-23 | .0000 | .0000 | .0498 | .7972 | .9292 | .8226 | .9045 | .8567 |
| 23-24 | .0000 | -.4243 | .6310 | .0518 | .4816 | .8320 | .9631 | .9991 |
| 24-25 | .0000 | .0000 | .0116 | .3334 | .8698 | .9322 | .9129 | .9890 |
| 25-26 | .0000 | .0000 | -.0113 | .4365 | .8234 | .9420 | .8944 | .9902 |
| 26-27 | .0000 | .0000 | -.1132 | .7709 | .6166 | .9498 | .9366 | .9933 |
| 27-28 | .0000 | .0000 | .0227 | .7193 | .9376 | .9705 | .9332 | .9597 |
| 28-29 | .0000 | .0000 | .4545 | .7548 | .6917 | .8361 | .8894 | .9630 |
| 29-30 | .0000 | .0000 | .4000 | -.4711 | .0890 | .8300 | .7246 | .7155 |
| 30+ | .0000 | .0000 | .5813 | -.2850 | .8731 | .7172 | .7781 | .4219 |

Table 6

Cell of Conversion Factor Having Highest One-Year Lagged Correlation With Conversion Factor of Cell to be Estimated - Fiscal Year 1974

| Years of Service | Paygrade | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | E-1 | E-2 | E-3 | E-4 | E-5 | E-6 | E-7 | E-8 | E-9 |
| 0-1 | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. | 1. |
| 1-2 | 2. | 2. | 3. | 3. | 2. | 2. | 2. | 3. | 3. |
| 2-3 | 1. | 1. | 2. | 3. | 3. | 1. | 3. | 3. | 3. |
| 3-4 | 1. | 1. | 1. | 1. | 2. | 2. | 3. | 2. | 3. |
| 4-5 | 1. | 1. | 3. | 1. | 2. | 3. | 2. | 2. | 3. |
| 5-6 | 1. | 1. | 2. | 3. | 3. | 2. | 2. | 3. | 3. |
| 6-7 | 2. | 1. | 2. | 3. | 2. | 2. | 3. | 3. | 3. |
| 7-8 | 1. | 2. | 2. | 2. | 2. | 2. | 1. | 3. | 3. |
| 8-9 | 2. | 3. | 2. | 2. | 2. | 2. | 2. | 2. | 3. |
| 9-10 | 2. | 2. | 2. | 2. | 2. | 3. | 3. | 2. | 3. |
| 10-11 | 2. | 3. | 2. | 2. | 2. | 2. | 2. | 2. | 3. |
| 11-12 | 2. | 3. | 1. | 2. | 2. | 2. | 3. | 3. | 3. |
| 12-13 | 2. | 3. | 2. | 2. | 2. | 2. | 3. | 3. | 3. |
| 13-14 | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 3. | 3. |
| 14-15 | 1. | 2. | 2. | 2. | 2. | 2. | 2. | 3. | 3. |
| 15-16 | 2. | 3. | 3. | 2. | 2. | 2. | 2. | 2. | 3. |
| 16-17 | 1. | 3. | 3. | 2. | 2. | 2. | 2. | 3. | 3. |
| 17-18 | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 3. |
| 18-19 | 2. | 3. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 19-20 | 1. | 2. | 2. | 2. | 2. | 2. | 2. | 2. | 3. |
| 20-21 | 2. | 3. | 1. | 1. | 2. | 3. | 3. | 3. | 2. |
| 21-22 | 2. | 3. | 2. | 2. | 2. | 2. | 2. | 2. | 3. |
| 22-23 | 2. | 3. | 1. | 2. | 2. | 2. | 2. | 2. | 2. |
| 23-24 | 2. | 3. | 2. | 3. | 2. | 2. | 2. | 2. | 3. |
| 24-25 | 2. | 3. | 2. | 2. | 3. | 2. | 2. | 2. | 2. |
| 25-26 | 2. | 3. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 26-27 | 2. | 3. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 27-28 | 2. | 3. | 2. | 2. | 2. | 2. | 2. | 2. | 2. |
| 28-29 | 2. | 3. | 2. | 3. | 2. | 2. | 2. | 2. | 2. |
| 29-30 | 2. | 3. | 2. | 1. | 2. | 2. | 2. | 2. | 2. |
| 30+ | 2. | 3. | 3. | 3. | 2. | 2. | 3. | 3. | 2. |

## Regression Estimates

Regression estimates of individual cell conversion factors were calculated based upon 6-year sequences of individual cell TAFMS/PEBD conversion factors. A bivariate regression model

$$F_{ijk} = \alpha_{ijk} + \beta_{ijk}F'_{i-1,j*,k*} + e_{ijk}$$

was used where $F_{ijk}$ represents the conversion factor for cell (j,k) for year i, and $e_{ijk}$ represents an error terms. $\alpha_{ijk}$ and $\beta_{ijk}$ were estimated using single-stage least squares techniques. (See Yamane, 1964, for a discussion of regression estimation.) Using arguments analagous to those used in the section discussing cell-by-cell conversion techniques, $F'_{i-1,j*,k*}$ was selected in four different ways (see footnote 4):

1. $F'_{i-1,j*,k*} = F_{i-1,jk}$; the conversion factor of the previous year.

2. $F'_{i-1,j*,k*} = F_{i-1,j-1,k}$; the conversion factor of the previous year's prior LOS cell.

3. $F'_{i-1,j*,k*} = F_{i-1,j-1,k-1}$; the conversion factor of the previous year's prior LOS cell and next lowest paygrade.

4. $F'_{i-1,j*,k*}$ = maximum single year lagged correlation $\{F_{i-1,jk}; F_{i-1,j-1,k}; F_{i-1,j-1,k-1}\}$ chosen in a manner equivalent to that discussed in the section detailing selection of TAFMS/PEBD conversion factor based upon cell with highest lagged correlation coefficient with cell to be estimated.[5]

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[5]For completeness, the regression model $F_{ijk} = \alpha_{ijk} + \beta_{1ijk}F_{i-1,jk}$ $\beta_{2ijk}F_{i-1,j-1,k} + \beta_{3ijk}F_{i-1,j-1,k-1} + e_{ijk}$ was analyzed. Due to the expected high variability encountered when as many as four regression parameters are estimated on the basis of only six data points, it was not expected that this technique would be especially useful. Results are available upon request from NAVPERSRANDCEN, Code 303. Consideration should be given to this model as the data base for estimation becomes larger.

## RESULTS

### Analysis of Mean Absolute Deviation

Each technique discussed in the previous section was used to convert TAFMS force structure matrices to PEBD for FY 1973-1976. For comparative purposes, an unconverted TAFMS matrix was also analyzed as a PEBD estimate.[6] Data was measured in terms of number of individuals per matrix cell. Table 7 lists the total ALNAV inventory for FY 1973-1976. Note that this study was conducted during a period of declining total enlisted personnel.

Table 7

Total ALNAV Enlisted Personnel Inventory
Fiscal Years 1973-1976

| Fiscal Year | Total ALNAV Enlisted Personnel Inventory |
|---|---|
| 1973 | 510,669 |
| 1974 | 490,009 |
| 1975 | 474,735 |
| 1976 | 465,748 |

Table 8 lists the mean absolute deviation between estimated and actual PEBD force structure matrices. Marginal techniques consistently recorded the highest mean absolute deviations and, therefore, performed poorest with regard to this criterion. Within the category of cell-by-cell conversion techniques, apportionment of the previous year TAFMS/PEBD conversion factor of the corresponding cell consistently recorded the lowest mean absolute deviation. This method reduced the deviation obtained from unconverted TAFMS matrices by approximately 54 to 64 percent. Within the category of regression techniques, the apportioned conversion factor with highest single-year lagged correlation coefficient consistently scored the lowest mean absolute deviation. Except for FY 1975, the mean absolute deviation of this method was almost identical to that obtained by the best cell-by-cell technique. For FY 1975, the mean absolute deviation of the best regression method was approximately 46 percent smaller than that of the best cell-by-cell method.

Note that, almost without exception, apportionment lowered the mean absolute deviation of estimates.

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[6]The estimated FY 1976 PEBD matrices obtained by each method and matrices showing deviations between estimated and actual PEBD inventories are available, upon request, from NAVPERSRANDCEN, Code 303.

Table 8

Mean Absolute Deviation Between Estimated and Actual PEBD Matrices

| | Conversion Method | Fiscal Year | | | |
|---|---|---|---|---|---|
| | | 1973 | 1974 | 1975 | 1976 |
| | Unconverted TAFMS Matrix | 386.2 | 316.7 | 261.3 | 241.6 |
| Marginal Methods | Six-Year Column Percentage Distribution | 480.0 | 425.9 | 431.4 | 384.5 |
| | Previous-Year Column Percentage Distribution | 357.6 | 307.2 | 262.8 | 233.9 |
| | Six-Year Row Percentage Distribution | 321.7 | 416.9 | 401.7 | 344.5 |
| | Six-Year Row Percentage Distribution-Apportioned | 260.8 | 289.4 | 320.7 | 306.8 |
| Cell-by-Cell Conversion Methods | Six-Year Moving Ratio Cell by Cell Conversion Factor | 216.9 | 193.3 | 213.1 | 229.9 |
| | Six-Year Moving Ratio Cell by Cell Conversion Factor-Apportioned | 191.8 | 161.7 | 152.4 | 197.0 |
| | Previous-Year Cell by Cell Conversion Factor | 148.6 | 126.9 | 116.9 | 113.9 |
| | Previous-Year Cell by Cell Conversion Factor-Apportioned | 139.4 | 118.5 | 105.8 | 111.5 |
| | Previous-Year Prior LOS Cell Conversion Factor | 330.4 | 301.4 | 237.8 | 218.0 |
| | Previous-Year Prior LOS Cell Conversion Factor-Apportioned | 324.1 | 285.6 | 238.8 | 160.3 |
| | Previous-Year Prior LOS, Paygrade Cell Conversion Factor | 289.9 | 303.6 | 260.8 | 260.8 |
| | Previous-Year Prior LOS, Paygrade Cell Conversion Factor-Apportioned | 232.7 | 278.6 | 232.8 | 216.5 |
| | Previous-Year Conversion Factor with Highest Correlation | 203.4 | 221.5 | 166.2 | 163.3 |
| | Previous-Year Conversion Factor with Highest Correlation-Apportioned | 206.4 | 245.5 | 158.1 | 142.5 |

Table 8 (Continued)

| | Conversion Method | Fiscal Year 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|
| Regression Estimates | Regression on Previous-Year Conversion Factor | 201.6 | 193.0 | 174.5 | 178.7 |
| | Regression on Previous-Year Conversion Factor-Apportioned | 177.3 | 154.5 | 148.2 | 157.4 |
| | Regression on Previous-Year Prior LOS Conversion Factor | 154.7 | 144.4 | 120.2 | 139.5 |
| | Regression on Previous-Year Prior LOS Conversion Factor-Apportioned | 131.2 | 116.4 | 90.8 | 138.7 |
| | Regression on Previous-Year Prior LOS, Paygrade Conversion Factor | 180.4 | 147.7 | 167.5 | 164.7 |
| | Regression on Previous-Year Prior LOS, Paygrade Conversion Factor-Apportioned | 157.7 | 123.1 | 114.4 | 148.8 |
| | Regression on Previous-Year Conversion Factor With Highest Correlation | 150.1 | 129.4 | 97.9 | 125.6 |
| | Regression on Previous-Year Conversion Factor With Highest Correlation-Apportioned | 130.7 | 113.0 | 57.5 | 113.7 |

## Analysis of Cost Estimates

Table 9 presents the standardized total ALNAV monthly pay for FY 1973 through 1976. All results are listed in dollars. The data indicate that this study was conducted during a period of declining standardized payrolls.

Table 9

Standardized Total ALNAV Monthly Pay for Enlisted Personnel--Fiscal Years 1973-1976

| Fiscal Year | Standardized Total ALNAV Monthly Pay for Enlisted Personnel |
|---|---|
| 1973 | $264,497,664 |
| 1974 | $253,347,638 |
| 1975 | $244,664,340 |
| 1976 | $239,679,184 |

Tables 10 and 11 contain the difference and percentage difference between standardized total ALNAV monthly pay calculated basis of the actual PEBD inventories and that obtained from the estimated PEBD inventories. Marginal techniques again perform poorly relative to the other methods under study.

Many apportioned cell-by-cell and regression procedures provide cost estimates with similar accuracy. Most procedures produce cost estimates with substantially smaller error than those that are obtained when the cost of the unconverted TAFMS matrix is used as an estimate of the cost of the corresponding PEBD matrix. Unconverted TAFMS data underestimated standardized costs by between approximately $2-3 million dollars, or approximately 1 percent, while procedures such as apportionment of the previous year TAFMS/PEBD conversion factor or apportioned regression on the conversion factor with highest single-year lagged correlation coefficient generally differed in cost by no more than $350,000 or approximately .13 percent of true standardized costs. Often, these methods yield cost estimates to within .10 percent of true standardized costs.

Table 10

Difference Between Estimated and Actual Standardized Total
ALNAV Monthly Pay for Enlisted Personnel - Fiscal Years 1973-1976

| Conversion Method | | Fiscal Year 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|
| | Unconverted TAFMS Matrix | $ -2,847,774 | $ -2,588,048 | $ -2,254,124 | $ -2,130,094 |
| Marginal Methods | Six-Year Column Percentage Distribution | $ -1,338,468 | $ -2,629,700 | $ -2,890,546 | $ -2,212,852 |
| | Previous-Year Column Percentage Distribution | -1,456,338 | -1,092,128 | -436,588 | 107,926 |
| | Six-Year Row Percentage Distribution | 433,208 | -610,800 | 2,037,666 | 1,973,418 |
| | Six-Year Row Percentage Distribution -Apportioned | -318,124 | -1,660,228 | -2,393,404 | -1,989,138 |
| Cell by Cell Conversion Methods | Six-Year Mcving Ratio Cell by Cell Conversion Factor | $ 5,821,784 | $ 10,001,192 | $ 13,985,510 | $ 11,776,132 |
| | Six-Year Moving Ratio Cell By Cell Conversion Factor-Apportioned | -480,670 | -370,182 | -144,676 | -9,164 |
| | Previous-Year Cell by Cell Conversion Factor | 4,066,724 | 5,584,704 | 5,451,208 | 1,490,414 |
| | Previous-Year Cell by Cell Conversion Factor-Apportioned | -308,398 | 111,984 | 243,778 | 144,978 |
| | Previous-Year Prior LOS Cell Conversion Factor | -34,301,462 | -27,906,006 | -23,662,474 | -22,982,656 |
| | Previous-Year Prior LOS Cell Conversion Factor-Apportioned | 1,405,968 | 926,578 | 780,210 | 441,844 |
| | Previous-Year Prior LOS, Paygrade Cell Conversion Factor | 14,528,612 | 18,203,308 | 18,367,632 | 17,742,648 |
| | Previous-Year Prior LOS, Paygrade Cell Conversion Factor-Apportioned | -402,584 | -395,708 | -392,594 | -63,168 |
| | Previous-Year Conversion Factor With Highest Correlation | -5,588,344 | -12,402,158 | -7,790,728 | -12,545,242 |
| | Previous-Year Conversion Factor With Highest Correlation-Apportioned | -308,914 | 50,510 | 486,508 | -101,416 |

Table 10 (Continued)

| | Conversion Method | Fiscal Year | | | |
|---|---|---|---|---|---|
| | | 1973 | 1974 | 1975 | 1976 |
| Regression Estimates | Regression on Previous-Year Conversion Factor | $ 7,576,396 | $ 12,235,308 | $ 13,052,038 | $ 6,599,030 |
| | Regression on Previous-Year Conversion Factor-Apportioned | -295,500 | -254,278 | 11,892 | 85,770 |
| | Regression on Previous-Year Prior LOS Conversion Factor | 5,383,916 | 6,481,398 | 8,081,594 | 3,986,016 |
| | Regression on Previous-Year Prior LOS Conversion Factor-Apportioned | -357,554 | -322,868 | 104,916 | 45,194 |
| | Regression on Previous-Year Prior LOS, Paygrade Conversion Factor | 4,363,768 | 6,025,856 | 14,407,068 | 7,821,970 |
| | Regression on Previous-Year Prior LOS, Paygrade Conversion Factor -Apportioned | -398,880 | -229,368 | -224,362 | -204,942 |
| | Regression on Previous-Year Conversion Factor With Highest Correlation | 4,786,424 | 4,407,720 | 7,998,686 | 2,502,348 |
| | Regression on Previous-Year Conversion Factor With Highest Correlation-Apportioned | -345,574 | -119,036 | -71,772 | 94,352 |

Table 11

Percentage Difference Between Estimated and Actual
Standardized Total ALNAV Monthly Pay for Enlisted Personnel
Fiscal Years 1973-1976

| | Conversion Method | Fiscal Year | | | |
|---|---|---|---|---|---|
| | | 1973 | 1974 | 1975 | 1976 |
| | Unconverted TAFMS Matrix | -1.08% | -1.02% | -.92% | -.83% |
| Marginal Methods | Six-Year Column Percentage Distribution | -.51% | -1.04% | -1.18% | -.92% |
| | Previous-Year Column Percentage Distribution | -.55% | -.43% | -.18% | .05% |
| | Six-Year Row Percentage Distribution | .16% | -.24% | .83% | .82% |
| | Six-Year Row Percentage Distribution-Apportioned | -.12% | -.66% | -.98% | -.83% |
| Cell by Cell Conversion | Six-Year Moving Ratio Cell by Cell Conversion Factor | 2.20% | 3.95% | 5.72% | 4.91% |
| | Six-Year Moving Ratio Cell by Cell Conversion Factor-Apportioned | -.18% | -.15% | -.06% | -.00% |
| | Previous-Year Cell by Cell Conversion Factor | 1.54% | 2.20% | 2.23% | .62% |
| | Previous-Year Cell by Cell Conversion Factor -Apportioned | -.12% | .04% | .10% | .06% |
| | Previous-Year Prior LOS Cell Conversion Factor | -12.97% | -11.01% | -9.67% | -9.59% |
| | Previous-Year Prior LOS Cell Conversion Factor -Apportioned | .53% | .37% | .32% | .18% |
| | Previous-Year Prior LOS, Paygrade Cell Conversion Factor | 5.49% | 7.19% | 7.51% | 7.40% |
| | Previous-Year Prior LOS, Paygrade Cell Conversion Factor-Apportioned | -.15% | -.16% | -.15% | -.03% |
| | Previous-Year Conversion Factor With Highest Correlation | -2.11% | -4.90% | -3.18% | -5.23% |
| | Previous-Year Conversion Factor With Highest Correlation-Apportioned | -.12% | .02% | .20% | -.04% |

Table 11 (Continued)

| Conversion Method | | Fiscal Year | | | |
|---|---|---|---|---|---|
| | | 1973 | 1974 | 1975 | 1976 |
| Regression Estimates | Regression on Previous-Year Conversion Factor | 2.86% | 4.83% | 5.33% | 2.75% |
| | Regression on Previous-Year Conversion Factor -Apportioned | -.11% | -.10% | .00% | .04% |
| | Regression on Previous-Year Prior LOS Conversion Factor | 2.04% | 2.56% | 3.30% | 1.66% |
| | Regression on Previous-Year Prior LOS Conversion Factor-Apportioned | -.14% | -.13% | .04% | .02% |
| | Regression on Previous-Year Prior LOS, Paygrade Conversion Factor | 1.65% | 2.38% | 5.89% | 3.26% |
| | Regression on Previous-Year Prior LOS, Paygrade Conversion Factor-Apportioned | -.15% | -.09% | -.09% | .09% |
| | Regression on Previous-Year Conversion Factor With Highest Correlation | 1.81% | 1.74% | 3.27% | 1.04% |
| | Regression on Previous-Year Conversion Factor With Highest Correlation-Apportioned | -.13% | -.05% | -.03% | .04% |

## CONCLUSIONS

Based upon an analysis of the PEBD matrices estimated by the various techniques discussed in this report, the following conclusions may be stated.

1. A TAFMS/PEBD conversion technique based upon the apportionment of regression estimates on the cell with highest single-year lagged correlation with the cell to be estimated resulted in highly accurate estimates of standardized force-structure cost. Apportionment of the previous year TAFMS/PEBD cell conversion factor, as well as a number of other cell-by-cell and regression techniques resulted in satisfactory cost estimates. Marginal techniques and, in general, unapportioned results yielded relatively poor cost estimates.

2. The mean absolute deviation of estimates produced by either an apportioned "best" linear regression technique or "best" cell-by-cell conversion procedure indicate that these procedures produce PEBD force structures that are significantly more accurate than those produced by naive utilization of unconverted TAFMS matrices.

3. Since procedures using previous-year data often outperformed methods using 6-year averages, investigation of procedures that weight yearly observations might prove beneficial.

## RECOMMENDATION

Among the techniques studied, the "best" regression technique and "best" cell-by-cell conversion method provided estimates with both relatively small cost errors and low mean absolute deviations. Because the "best" regression technique considers the flow of personnel through the force structure, it is recommended that this procedure be implemented to estimate the cost of TAFMS matrices.

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